

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Washington Headquarters Service, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington, DC 20503.

PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.

1. REPORT DATE (DD-MM-YYYY) 15-03-2011	2. REPORT TYPE Master of Military Studies Research Paper	3. DATES COVERED (From - To) September 2009 - April 2010		
4. TITLE AND SUBTITLE UNMANNED GROUND VEHICLES IN SUPPORT OF IRREGULAR WARFARE: A NON-LETHAL APPROACH		5a. CONTRACT NUMBER N/A		
		5b. GRANT NUMBER N/A		
		5c. PROGRAM ELEMENT NUMBER N/A		
6. AUTHOR(S) Major David M. Moreau/USMC		5d. PROJECT NUMBER N/A		
		5e. TASK NUMBER N/A		
		5f. WORK UNIT NUMBER N/A		
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) USMC Command and Staff College Marine Corps University 2076 South Street Quantico, VA 22134-5068		8. PERFORMING ORGANIZATION REPORT NUMBER N/A		
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) N/A		10. SPONSOR/MONITOR'S ACRONYM(S) N/A		
		11. SPONSORING/MONITORING AGENCY REPORT NUMBER N/A		
12. DISTRIBUTION AVAILABILITY STATEMENT Unlimited				
13. SUPPLEMENTARY NOTES N/A				
14. ABSTRACT Due to the unique demands of Irregular Warfare (IW), a variety of technological shortfalls, and the legal, moral, and ethical issues surrounding armed unmanned system capabilities, Unmanned Ground Vehicle development should be focused at meeting the challenges associated with future warfare as a Reconnaissance, Surveillance, and Target Acquisition (RSTA) platforms, not as systems capable of employing lethal force on the battlefields of tomorrow.				
15. SUBJECT TERMS Unmanned Ground Vehicles (UGV), Armed UGV, Reconnaissance Surveillance Target Acquisition (RSTA), Lethal Unmanned Systems, Irregular Warfare				
16. SECURITY CLASSIFICATION OF: a. REPORT Unclass b. ABSTRACT Unclass c. THIS PAGE Unclass		17. LIMITATION OF ABSTRACT UU	18. NUMBER OF PAGES 45	19a. NAME OF RESPONSIBLE PERSON Marine Corps University / Command and Staff College
				19b. TELEPHONE NUMBER (Include area code) (703) 784-8330 (Admin Office)

United States Marine Corps
Command and Staff College
Marine Corps University
2076 South Street
Marine Corps Combat Development Command
Quantico, VA 22134-5068

MASTER OF MILITARY STUDIES

**UNMANNED GROUND VEHICLES IN SUPPORT OF IRREGULAR WARFARE:
A NON-LETHAL APPROACH**

SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF MILITARY STUDIES

MAJOR DAVID M. MOREAU/USMC

AY 10-11

Mentor and Oral Defense Committee Member: _____

Approved: David Moreau

Date: 14 March 2011

Oral Defense Committee Member: _____

Approved: Edward Burton

Date: 14 March 2011

Executive Summary

Title: Unmanned Ground Vehicles in Support of Irregular War: A Non-lethal Approach

Author: Major David M. Moreau, United States Marine Corps

Thesis: Due to the unique demands of Irregular Warfare (IW), a variety of technological shortfalls, and the legal, moral, and ethical issues surrounding armed unmanned capabilities, UGV development should be focused at meeting the challenges associated with future warfare as a Reconnaissance, Surveillance, and Target Acquisition (RSTA) platform, not as a system capable of employing lethal force on the battlefields of tomorrow.

Discussion: Within the last 10 years, U.S. unmanned technology has matured to a degree where it is common for commanders to authorize the use of lethal force from Unmanned Aerial Systems (UAS) flying high above the battlefield. Engaging threat forces in austere, remote locations without having to accept the associated risk of placing personnel in aircraft or vehicles during the conduct of the mission is here, and will continue to grow as the role of unmanned systems in support of military operations increases over time.

There exists a community of interest who wish to take the aforementioned UAS model and apply it to ground combat operations where armed Unmanned Ground Vehicles (UGVs) will one day fight alongside warfighters on future battlefields. Unfortunately, shortfalls in communications, mobility, and autonomy hinder UGV use, eliminating them from participating in the more dynamic operations associated with war.

The nuances of IW, i.e. proximity of the population to combat operations, asymmetric tactics, and ambiguous situations where the decision to employ lethal force is exceedingly difficult, challenges today's small unit leaders in their ability to maintain situational awareness on the battlefield. Providing UGVs specifically designed for RSTA missions are a logical choice at increasing situational awareness for the small unit by extending their eyes and ears into areas deemed inaccessible or impractical for human presence for extended periods of time.

The development and use of lethal UGVs may result in a proclivity for war, and should the technology find its way into the hands of less responsible factions or rogue nations, proliferation of lethal unmanned technology may occur. Of the many challenges associated with IW, target location and identification within a civilian population is one that relies heavily on well-trained warfighters and advanced Intelligence, Surveillance, and Reconnaissance (ISR) technology. It is in this role where future UGV development should be focused, not with the development of lethal payloads.

Conclusion: Technological shortfalls and the legal, moral, and ethical ramifications of applying lethal force through a system where a human may or may not be in the proverbial control-loop deserves long-term analysis, and should not be an afterthought during UGV development and experimentation.

DISCLAIMER

THE OPINIONS AND CONCLUSIONS EXPRESSED HEREIN ARE THOSE OF THE INDIVIDUAL STUDENT AUTHOR AND DO NOT NECESSARILY REPRESENT THE VIEWS OF EITHER THE MARINE CORPS COMMAND AND STAFF COLLEGE OR ANY OTHER GOVERNMENTAL AGENCY. REFERENCES TO THIS STUDY SHOULD INCLUDE THE FOREGOING STATEMENT.

QUOTATION FROM, ABSTRACTION FROM, OR REPRODUCTION OF ALL OR ANY PART OF THIS DOCUMENT IS PERMITTED PROVIDED PROPER ACKNOWLEDGEMENT IS MADE.

PREFACE

The following paper is the result of a professional interest in Unmanned Ground Vehicle (UGV) technology in support of military operations. This interest originated during a tour at the Marine Corps Warfighting Lab as the Project Officer for the *Dragon Runner UGV*. From initial concept development, to its Operational Evaluation in support of Operation IRAQI FREEDOM, *Dragon Runner* provided answers to many questions surrounding UGV use in Irregular War, specifically counterinsurgency operations. As the program matured, and payloads were developed, the question of one day arming UGVs became a contentious topic of debate. Consequently, researching lethal UGV use in support of military operations has been of interest, and the Master of Military Science program provided the opportunity to do so.

Support for the paper spans nearly a decade, derived mainly from long-standing relationships with friends and colleagues in academia, research and development, and the military. I would like to express my gratitude to the leadership of the Warfighting Lab during the development and testing of *Dragon Runner*. Thanks goes to the engineers at the Naval Research Lab and Carnegie Mellon University's Robotics Institute/National Robotics Engineering Consortium for designing the early test systems and prototypes. To Dr. Hagen Schempf, a sincere thanks goes to you for taking DRAGON RUNNER and the collective vision to the next level, making it a reality for years to come.

To the faculty of Command and Staff College, specifically Dr. Paulette Otis, thank you for your time and support throughout the development of this paper.

Finally, to my wife Christine, thank you for untiring support and sacrifice.

Table of Contents

DISCLAIMER.....	i
PREFACE.....	ii
INTRODUCTION.....	1
BACKGROUND.....	5
FOCUS AREA 1: NUANCES OF IRREGULAR WARFARE.....	10
FOCUS AREA 1 CONCLUSION.....	15
FOCUS AREA 2: MOBILITY, COMMUNICATIONS, AND AUTONOMY.....	17
FOCUS AREA 2 CONCLUSION.....	22
FOCUS AREA 3: ETHICAL, MORAL, AND LEGAL ISSUES.....	23
FOCUS AREA 3 CONCLUSION.....	27
OVERALL CONCLUSION.....	28
APPENDIX A.....	30
APPENDIX B.....	31
APPENDIX C.....	32
APPENDIX D.....	33
ENDNOTES.....	34
BIBLIOGRAPHY.....	38

Introduction

An ability to wage war remotely, through the use of unmanned systems has captured the imagination of engineers, military leaders, and policy makers throughout history, leading to the development of the torpedo and the first Unmanned Aerial Vehicles (UAV) during World War I. The thought of directing an unmanned system into an area where human access is unrealistic is appealing, especially for commanders bearing the responsibility of sending troops into combat with the understanding that many may not survive.

Within the last 10 years, U.S. unmanned technology has matured to a high degree of fidelity, instilling a sense of confidence in commanders and system controllers alike. It is now routine to engage enemy personnel and even provide friendly fire support through the use of armed Unmanned Aerial Systems (UAS), formerly UAVs, tethered along a control network that can extend several thousand miles from the combat zone into relative safety where the controller sits.

The reality of fighting threat forces in austere, remote locations without having to accept the risk associated with placing personnel in aircraft or vehicles during the conduct of the mission is here, and will continue to grow as the role of unmanned systems in support of military operations matures.

There exists a community of interest made up mostly of industry, military leadership, and law makers who wish to take the aforementioned UAS model and apply it to ground combat operations where armed Unmanned Ground Vehicles (UGVs) will one day fight alongside warfighters during combat operations.

The U.S. Army and Marine Corps have in fact invested in this technology with the development of Special Weapons Observation Remote Direct-Action System (*SWORDS*) and

Gladiator, both armed UGVs. (See Appendix A) On the surface, the development of lethal UGVs seems like a natural progression of technology, as a means to reduce manpower or mitigate the loss of life, but when closely examined, there are many issues and unanswered questions associated with armed UGV employment in support of Irregular Warfare (IW).

Technological shortfalls and the legal, moral, and ethical ramifications of applying lethal force through a system where a human may or may not be in the proverbial control-loop deserves long-term analysis and should not be an afterthought during UGV and/or lethal payload development.

Thesis: Due to the unique demands of IW, a variety of technological shortfalls, and the legal, moral, and ethical issues surrounding armed unmanned capabilities, UGV development should be focused at meeting the challenges associated with future conflict as a Reconnaissance, Surveillance, and Target Acquisition (RSTA) platform, not as a system capable of employing lethal fires on the battlefields of tomorrow.

Focus Area 1: Nuances of Irregular War

It is impossible to predict the exact future when it comes to war, yet assessments must be made in order to focus our country's response to any number of crises or contingencies requiring military intervention.¹ Future threats to the U.S. and its interests have been assessed as irregular in nature and will likely require more than military measures alone to restore peace as the condition of unrest may be economic, political, or social in nature - or all of the above.²

Irregular forces adopt asymmetric tactics in order to reduce the technological disadvantage they have when facing superior militaries like the U.S.³ Population support is central to both sides' success in IW, whereas the population remains largely on the periphery in

conventional or regular warfare. As witnessed in Iraq and Afghanistan during the counterinsurgencies, fighting in and amongst a population creates significant challenges for the small unit, e.g. difficulty at targeting a non-uniformed enemy, collateral damage considerations, and the increased demand for positive identification (PID) of a hostile act (HA) and/or hostile intent (HI) prior to employing lethal force.

Part one of this paper will briefly examine the efficacy of RSTA-specific UGVs at supporting military operations in IW, instead of UGVs outfitted with lethal payloads.

Focus Area 2: Mobility, Communications, and Autonomy Shortfalls

There are significant technological shortfalls in UGV development that lead them toward supporting less dynamic missions, e.g. reconnaissance and surveillance, or perimeter security, instead of force on force. U.S. developers must overcome shortfalls such as mobility, communications, and autonomy, plaguing current UGV development.⁴ Mobility may sound fairly straight forward, i.e. moving from point A to point B, but tele-operating a UGV through the use of sensors or electro-optical (EO), infra-red (IR) suites, is at times like driving a car while looking through binoculars. Limitations in field of view and the lack of real-time auditory senses facilitating depth perception inhibit dynamic tele-operation of UGVs required to effectively fight alongside warfighters, or under circumstances where the fluid nature of combat places forces in proximity to non-combatants and no-shoot decisions are made near instantaneously.

From a communications standpoint, regardless if the UGV is RSTA-specific or armed, the system must be able to effectively transmit data as a means of control and to increase situational awareness, thereby facilitating decision-making. Environmental factors that diminish

frequency transmission and reception pose major challenges for UGV developers, as does the ever-increasing battle for bandwidth.

For UGVs to be of value in IW, or any warfare for that matter, autonomy must be incorporated in their design to ensure certain actions are executed in lieu of human control, e.g. loss of communications, and fail-safe procedures for lethal payloads. Autonomy, utilizing Artificial Intelligence (AI) is a necessity for armed UGVs as the system must be able to execute the requisite decision-making prior to employing lethal force unless the environment is controlled or static, e.g. perimeter defense.

Part two of the paper will delve into the technological challenges associated with UGV development, and highlight the mobility, communications, and autonomy shortfalls as related to lethal payload employment.

Focus Area 3: Ethical, Moral, and Legal Issues

Applying lethal force in war often requires split second decision-making prior to engagement. IW is synonymous with close contact with the enemy, where the fighting often takes place in and among the population, and where collateral damage may negatively impact peaceful negotiations with the population months, if not years. Designing a UGV that incorporates autonomy or Artificial Intelligence (AI) to the degree that decision-makers become confident in authorizing autonomous/semi-autonomous armed UGV operations may not be a step in the right direction. Issues specific to *jus in bello* (just war theory) become apparent when considering the ramifications of developing a lethal UGV so effective at killing, adversaries will have no ability to counter it and may resort to an extreme, e.g. increasing acts of terrorism, targeting civilian populations, etc.⁵

Achieving this level of warfighting capability through the use of advanced armed UGVs might desensitize the owning government to the horrors of war, making it attractive or developing a proclivity for waging it. It may even lead to an arms race for lethal autonomous systems.

The final part of this paper will discuss the ethical, moral, and legal issues surrounding the development and employment of armed UGVs.

Background

The development of self-propelled torpedoes and the remotely piloted vehicle (RPV) during World War I paved the way for follow-on research and development of unmanned systems in support of military operations. Realizing the potential success of attacking the enemy while maintaining the element of surprise led the Germans to increase its U-boat fleet that relied on the torpedo to inflict heavy casualties to allied shipping. German ingenuity continued during World War II with the advancement of telemetry and rocket propulsion in their V-1 and V-2 long-range auto-piloted bombs and the fielding of the first tethered UGV, *Goliath*, designed to deliver a 130-pound explosive charge upwards of a mile away to attack allied armor.⁶ (See Appendix B) While not achieving success during the war due to its inability to negotiate severe terrain, lengthy control cables, and thin protective skin, *Goliath* did in fact pave the way for post-war concepts in unmanned system development.

The Vietnam War expanded unmanned system development as the U.S. emplaced numerous Unattended Ground Sensors (UGS) along the border between Laos and Cambodia in an effort to detect North Vietnamese and Viet Cong movement on the Ho Chi Minh Trail. Unmanned system development then slowed post-Cold War, with the exception of a handful of

Unmanned Aerial Vehicle (UAV) programs. No longer facing a bi-polar world, the U.S. soon found itself dealing with non-actor, or non-nation state threats as the power vacuum from Soviet collapse freed peoples harboring long-standing disagreements with neighboring groups. Animosity among these groups eventually led to conflict, often occurring in remote areas, lacking government and police. Access to these areas can be challenging and is where the use of unmanned systems seems like a logical solution. Post-Cold War unmanned systems development focused primarily on UAVs, as politics often prevented the deployment of U.S. forces on the ground in many instances.

During the 1991 Persian Gulf War, UAVs were used as a means to gather real-time imagery of Iraqi positions within Areas of Interest, and aided in the adjustment of supporting arms, acting as an airborne forward observer. A unique event in military history occurred as personnel aboard the battleship *USS Wisconsin* remotely piloted an RQ-2A Pioneer UAV over the heads of Iraqi soldiers on Faylaka Island, near Kuwait City. By raising their arms toward the sky as a symbol of surrender, the Iraqi's on Faylaka became the first military personnel in history to do so to an unmanned system.⁷ Each time the small drone had previously circled overhead, the Iraqis would receive effective indirect fire. It was during a follow-on RQ-2A Battle Damage Assessment (BDA) mission over Faylaka that the Iraqis determined that they had had enough of the bombing, and hoped that whoever was piloting the UAV recognized their capitulation. Suffice to say, more than just the crew of the *Wisconsin* watched this historic event. Future investment into UAV, now termed UAS technology, was secured over the next decade as systems became institutionalized in the U.S. military, just in time for the terrorist attacks of September 11th 2001, and subsequent Operation ENDURING FREEDOM.

On November 5th, 2002, another milestone in unmanned system development occurred when a Central Intelligence Agency controlled Predator UAV fired a Hellfire missile into the moving car containing Qaed Salim Sinan al-Harethi, al-Qaeda's senior operator in Yemen.⁸ Deemed routine today, this example of High Value Individual (HVI) targeting by the U.S. continues to disrupt and degrade al-Qaeda throughout their safe havens. At the same time the Predator in Yemen found its target, the U.S. military and coalition partners were staging forces for the eventual invasion of Iraq in March 2003.

As the invasion of Iraq commenced under Operation IRAQI FREEDOM, no one expected the exponential increase of UGV use once Phase-IV operations began, and the war rapidly shifted to counterinsurgency operations (COIN). Coalition forces faced asymmetric tactics from insurgents and foreign fighters alike, who shared a common weapon in the Improvised Explosive Device (IED), and in response, Explosive Ordnance Disposal (EOD) and Combat Engineer teams trained to identify and render-safe IEDs were in high demand in order to maintain mobility throughout the Combined-Joint Operations Area (CJOA). Many of the missions performed by these two organizations throughout Iraq, and now Afghanistan, utilize UGVs that are purpose-built to tele-operate human functionality in order to remotely work on IEDs. When the U.S. invaded Iraq in 2003, there were no UGVs on the ground. In response to the growing IED threat, the U.S. deployed 150 systems to Iraq by the end of 2004. By the end of 2005, the number of UGVs in country had risen to 2,400, and by 2008, peaked at 12,000 in various shapes and sizes to deal with the IED mission.⁹

Lessons learned regarding UGV use derived from the study of real-world operations and joint and service-level experimentation led to the multi-service requirement for a family of UGVs ranging from back-packable to systems as large as a tank. Integrated with mission-

specific payloads, these UGVs are being designed to enhance warfighting capabilities in support of IW. UGVs designed as mobile sensors, e.g. the Marine Corps' *Dragon Runner*, are an example of a non-lethal systems aimed at increasing the situational awareness of small units operating in a variety of environments while conducting a myriad of missions. (See Appendix B) In addition to these RSTA-specific UGVs like *Dragon Runner*, others have been developed with an ability to defend themselves or neutralize threats across the Range of Military Operations (ROMO) by firing lethal weapon systems.

The concept of armed UGVs has been debated over the years and researched within forward-looking organizations such as the Defense Advanced Research Projects Agency (DARPA). Early systems designed for Advanced Concept Technology Demonstrations (ACTD) paved the way for follow-on development of systems like the Modular Advanced Armed Robotic System (MAARS), an armed UGV designed to provide the warfighter a configurable capability based upon the type of threat or mission. (See Appendix C) Assessments have been made to identify cost and manpower savings should UGVs be integrated in support of some of the warfighting functions. It is estimated that the cost of an average soldier during a 20 year career, to include retirement, averages \$4 million, whereas a UGV costing a mere 10% of that figure could execute the same/similar tasks expected of the soldier throughout a career. Once obsolete, no long-term loss is incurred by the government over a UGV life cycle as industry can simply build another one.¹⁰ On the other hand, it is possible that without human leadership obtained through years of professional service and combat experience, UGVs might lack the required levels of operation to succeed in battle. For example, RSTA-specific UGVs used in EOD missions are largely successful as a result of the technician's overall military experience. All the UGV does is what it's commanded to do, and the linkage between experienced warfighter and

successful UGV operation cannot be underestimated. Will the armed UGV operator be a young, inexperienced soldier or Marine, or will he/she be a seasoned warfighter who understands combat? Will there actually be a cost savings at all if armed UGV missions require experienced warfighters? Combat requires split-second decision-making when deciding to use lethal force. The armed UGV may actually require multiple operators; one to control the direction of the UGV, another to maintain overall situational awareness, and possibly a third to release lethal munitions at the right time and place. Where would these operators come from and what would the prerequisites be to control a lethal UGV on the ground, alongside friendly, dismounted warfighters and the civilian population?

The advantages of UGV use cannot be overlooked, they do not get hungry, nor are they afraid. They follow orders, have a 24-hour, 7-day a week potential for operation, and will never suffer from Post Traumatic Stress Disorder.¹¹

The question remains, should UGVs possess a lethal capability? When one begins to compare and contrast the nuances of IW, and what is required in order to succeed, the RSTA-specific UGV is a logical choice. On the other hand, the ability to wage portions of a ground war remotely while minimizing friendly loss of life through the use of UGVs certainly has merit. The following sections will briefly address several major issues in UGV research and hopefully provide the reader with enough information to make a decision as to where the UGV development path in support of IW should lead. One thing is for certain, UGVs are here to stay and it is up to the Department of Defense to determine a proper road map for procurement and fielding. The U.S. Congress mandated in 2001 that by 2010, 1/3 of all combat aircraft will be unmanned and by 2015, 1/3 of all ground vehicles will be unmanned.¹² The services have not met this requirement, largely due to the war efforts and reduced budgets, although investments

have been made in UAS technology to increase their production, specifically in the area of Intelligence, Surveillance, and Reconnaissance (ISR) capabilities. UGV programs for the Army and Marine Corps remain under the control of the Robotic Systems Joint Program Office (RSJPO), where at least one variant under development is armed.

Focus Area 1: Nuances of Irregular War

Unmanned systems designed to increase situational awareness at any level are a valuable commodity to the warfighter. As discussed earlier in the paper, UAV use during the largely conventional Gulf War with Iraq paid dividends in providing indicators and warning of Iraqi troop movement, facilitating the joint targeting cycle. ISR systems are in greater demand where the enemy is among the population, and in some instances, is a segment of the population as is the case in IW. Targeting becomes a major challenge at all levels, and the use of lethal force can at times require the highest levels of authorization. Unmanned systems that provide the electronic eyes and ears for commanders in these situations are well regarded and considered a high demand, low density asset.

Irregular Warfare (IW) is defined as, “a violent struggle among state and non-state actors for legitimacy and influence over the relevant population(s). Irregular warfare favors indirect and asymmetric approaches, though it may employ the full range of military and other capacities, in order to erode an adversary’s power, influence, and will.”¹³ The subsets of IW are Counter Insurgency (COIN), Unconventional Warfare (UW), Stability Operations, Counter Terrorism (CT), and Foreign Internal Defense (FID). The indigenous population is at the center of the IW environment where the belligerents vie for influence and support from the people. In conventional, or regular warfare, the population largely remains on the periphery as two

belligerents fight each other's militaries on a mostly symmetric battlefield. IW poses a myriad of challenges for the regular force tasked with fighting the irregular force. Asymmetric tactics are the norm in IW, and come in a variety of forms such as the use of IEDs, the gravitation to urban areas, and the fact that irregular forces do not wear uniforms, making it nearly impossible to identify them from non-combatants unless they commit a hostile act or demonstrate hostile intent.¹⁴

In the wake of IRAQI and ENDURING FREEDOM, the Department of Defense (DOD) spent billions of dollars supporting the Services at training and equipping warfighters to deal with the challenges associated with IW. At the tactical level, the IW fight takes place at the battalion-level and below, and in a context where decentralized operations are required to ensure maximum contact and interaction with the population. Company and Platoons are provided assets usually reserved for higher echelons, e.g. communications, ISR, and at times, additional manpower.

Of all the requirements in support of the small unit, those technologies that increase situational awareness are often the single-most valuable capabilities in support of small unit leader decision-making. The fact that IW pits a uniformed force against a non-uniformed force, being able to positively identify friend from foe is of the utmost importance, and by extension, supports force protection measures. The goal in IW is influence over the population, and any collateral damage, i.e. killing non-combatants alienates the population, and also plays into the enemy's hands, potentially having strategic implications. Joint and Service-level IW experimentation routinely identifies the requirement for increased situational awareness at the small unit-level, supporting decision-making, and has inserted technology over the years in attempts to do just that. UGV development to date has, for the most part, focused on providing

capabilities to the small unit in dealing with the IED threat, falling in the RSTA-specific category. If the assessments hold true that future conflicts will be irregular in nature, where fighting amongst the people is the environment, and the objective is not the destruction of the opposing force, but influencing the people, technology designed at increasing situational awareness in an ISR or RSTA context is vital to success from the perspective of targeting, security, and force protection.

As an enabler, ISR/RSTA technology is valuable for U.S. small units while conducting COIN operations in Afghanistan. Not surprising, the primary mission for RSTA-specific UGVs is counter IED as it is the enemy's primary means of inflicting casualties on coalition forces in Afghanistan. From locating and identifying, to the rendering safe of the unexploded ordnance, RSTA-specific UGVs and other ISR capabilities facilitate control of key terrain and support mobility throughout the battlespace while reducing the potential for loss of life or limb.

Analytical Point #1

The nuances of IW demand increased situational awareness at the lowest tactical levels. UGVs designed for RSTA missions, or more simply put, extending the eyes and ears of the small unit provides a much-needed capability for ground forces. Whether the mission is to clear and hold, or find and fix, RSTA-specific technology supports the IW force by improving the contact rate with the enemy, deemed necessary at establishing security for the population in support of civil action development.¹⁵

By their nature, IW enemy forces exploit the seams and boundaries between friendly forces and population centers, all the while enjoying relative freedom of movement throughout the battlespace. A major challenge for friendly forces is locating the enemy in these areas at the

right time and place to either capture or kill them, while protecting the local populace from ensuing violence. Often, one must wait until the enemy actually commits a HA or demonstrates HI before authorization to employ lethal force is allowed under the Rules of Engagement (ROE). The U.S. military acknowledged that it must further develop certain capabilities in order to succeed at the 23 missions associated with IW.¹⁶ These capabilities come in the form of individual and unit training, command and control (C2) systems, tactical UAS, and Unattended Ground Sensors (UGS), designed specifically for the small unit. These systems extend the operational reach of tactical units and facilitate economy of force operations by increasing RSTA endurance and persistence in an attempt to elevate situational awareness of the surrounding areas, i.e. increasing the chances of being in the right place at the right time to confront the enemy.¹⁷

Combat operations in IW are more dispersed and within a non-linear battlespace, requiring demands for force protection in all directions and at all times. The enemy seeks not to confront you in large numbers, but employ hit and run tactics aimed at inflicting casualties over an extended period of time in hopes that popular support for the friendly force diminishes. The enemy in IW is elusive, fairly self-reliant, and maintains an ability to influence the population for support through intimidation of the use of social media/digital technology.¹⁸ Terrain in IW is not simply cleared, then passed off to the local population as the friendly force moves to another area. It must be secured for the duration of the conflict and maintained in order for the host nation government to one day take control in a self-sustaining fashion. In other instances, the terrain must be secured until elections are held and a government is formed, which may take months or years.¹⁹

Analytical Point #2

Because IW is largely fought in and among the population, highly trained, professional forces are required to combat threats that use asymmetric tactics as a means of closing the technology gap. Herein lies the challenge, as an asymmetric tactic is to hide amongst the population when the threat is not local. In other cases, the threat may be part of the indigenous population, thereby defaulting automatically to projecting force from within largely non-combatant areas. Discriminating between friend and foe, or non-combatant from enemy combatant is very important as the unintentional killing of innocent civilians can have strategic implications. Intelligence collection is often one of the overriding keys to success in IW. General Sir Frank Kitson of the British Army, in his book, "Low Intensity Operations", 1971, said that, "if it is accepted that the problem of defeating the enemy consists very largely of finding him, it is easy to recognize the paramount importance of good information."²⁰

The U.S. military is exceptional at killing the enemy through the employment of direct and indirect fire, but the prerequisite is always target acquisition and identification. Unfortunately, intelligence collection suffers in IW due mainly to the cultural divide between the civilian population and the foreign military force. As a result, real-time ISR is synonymous with IW as a means of reducing the impact of, at times, marginal intelligence as demonstrated by the ever increasing demand for a persistent capability in Afghanistan aimed at identifying hostile activity.²¹

Civilian populations that enjoy immunity in conventional warfare, find themselves in the midst of conflict in IW.²² In order for the U.S. to effectively conduct operations in IW, it must spread its force out amongst the population to develop relationships with the people, and establish security of an area so that the enemy's presence is no longer welcome. Support, in a

variety of forms, is pushed down to these small units living amongst the population, and a greater reliance on decision-making is required.²³ Small units fighting IW often operate in austere locations, where access to the population becomes vital to achieving success. It is in this environment that warfighters are required to make split-second decisions, determining who within the population is vulnerable to the effects of lethal force, who should be protected, and who should be killed.²⁴ For armed UGVs to effectively support IW, as described above, they must demonstrate significant abilities at dealing with uncertainty, incomplete information, and possess human-like intuition at identifying patterns of life. Is this a bridge too far technologically? At the moment it is, but it is not inconceivable that developers will one day achieve a level of autonomy in ground robotics that could pave the way for fully autonomous armed UGVs.

Analytical Point #3

If the requirement is increasing situational awareness for the small unit, arguably the technology is available, e.g. mobile ground sensors used to look around a corner, under a vehicle, or establish an electronic listening post or observation post. If the need is to extend the eyes and ears of the small unit, a variety of RSTA-specific UGVs, e.g. *Dragon Runner*, *Talon*, *Packbot*, etc are available and have EO/IR payloads for this very use. Currently, these systems provide support to the IED mission, but could easily receive modification to support information-gathering tasks in support of IW.

Aerial reconnaissance and surveillance with UAS technology is being developed at a rapid pace, enjoying a nearly obstacle-free maneuver space, whereas UGV development faces an array of manmade and natural obstacles to contend with. COIN operations in Iraq showed that IW

often requires less kinetic action to succeed, and when lethal force must be applied, the decision to do so is left up to the individual warfighter. Does the U.S. military ever want to relinquish this authority to an unmanned system roving the battlefield? Is the U.S. military willing to separate the man in the control loop from what the machine is doing, which would be the case in fully autonomous UGVs? RSTA-specific UGVs fill gaps where UAS is unable to look, and where human access is not possible, and can PID HA/HI of an enemy combatant, support decision-making, and effectively close the targeting loop. This arguably is where UGV development should focus, not on an ability to remotely kill.

Focus Area 1 Conclusion

IW places unique demands on the warfighter due to the proximity of the population to military operations. The ever-present reality is the fact that the people's support is the goal for both sides of the conflict, not the destruction of the adversary's war-making ability. The slightest negative impact, whether physically or psychologically, that separates the friendly force from the population, e.g. collateral damage, makes working and living with the people that much harder.²⁵

The wars in Iraq and Afghanistan highlight the difficulty in obtaining accurate, and timely intelligence on the enemy and have to a degree forced the demand for persistent ISR. ISR, primarily UAS, increases the probability of identifying enemy activity, but much of the time it is a case of being in the right place at the right time. RSTA-specific UGVs have proven their worth in the counter-IED mission, saving countless lives by rendering-safe unexploded ordnance jury rigged to detonate by a myriad of initiating devices.

It would not take a great deal of effort to learn from the IED missions and adopt new

tactics, techniques, and procedures focused at employing RTSA-specific UGVs in scenarios where ground observation is vital to maintaining security in a local area. In IW, particularly COIN, units must not only clear the ground of the enemy, but also hold it until such time the local population can provide its own security. This mission is by and large the responsibility of the infantryman, with assistance from civil-military specialists that work with the population. It is time consuming and requires vigilance in maintaining a secure environment for the people to live their day-to-day lives. To augment the aerial observation capability UAS provides to the small units providing security while living amongst a local population, RSTA-specific UGVs should be used to enhance situational awareness, increasing the eyes and ears of an already overburdened small unit, and not engaging the enemy with lethal force.

Does it make sense to develop armed UGVs that are unable to converse with the population, or develop relationships, but do in fact increase the potential for placing those people we must protect in harm's way through the use of lethal force?

Focus Area 2: Mobility, Communications, and Autonomy Shortfalls

The nuances associated with IW pose a challenge to the warfighter, as do the technological challenges for the UGV in the areas of mobility, communications, and autonomy. No matter the type of UGV, RSTA-specific, or armed platform, the ability to move, communicate, and execute tasks in the absence of human interface through autonomy is imperative to its success on the battlefield. The following sections will attempt to highlight the points deemed most challenging for armed UGV development, and also relate the challenges to RSTA-specific UGV development as well.

Analytical Point #1

The ability for UGVs to negotiate difficult terrain has challenged science and industry for years, and falls well short of achieving a level of performance required to effectively work with/among military units operating in most, if not all environments under dynamic situations. In the last 20 years, science and academia have developed unique and innovative ways in which tele-operated and autonomous machines overcome both man-made and natural obstacles. Some systems articulate, others crawl, while others walk upright akin to a quadruped while negotiating terrain.

Autonomous systems remain exclusively in prototype form and serve as a test-bed for the advancement of software, enabling continued research and development. RSTA-specific UGVs currently in use by the U.S. military are all tele-operated, each requiring one or more personnel to control the system's actions. None achieve levels of mobility that would allow them to participate in high tempo, fluid operations, e.g. attacks or raids. For the most part, these systems are slow moving, and require deliberate input via their Operator Control Units (OCUs) that serve as the command and control link from operator to UGV. UGV mobility is measured not only by how well the vehicle negotiates terrain, but also how well an operator remotely controls it through the OCU. OCUs in form and function may mirror a home gaming console controller in size and simplicity, or be as large as a small laptop, providing multiple options for control. (See Appendix D) Operating a modern UGV is in many ways like playing a video game, where spatial relationship regarding obstacles is virtual and depicted on the OCU screen, or maintained through memorizing key features of the surrounding area while operating the UGV.

This tele-operation unfortunately results in decreased mobility as too often the operator miss-judges the proximity of obstacles due to the lack of depth perception on the OCU monitor;

or simply forgets about a rock that is adjacent to the UGV. Missions like counter IED require slow, deliberate movement over varying types of terrain, and today's OCUs provide the required Human Robot Interaction (HRI) to safely and efficiently tele-operate RSTA-specific UGVs to and around the IED.²⁶ These aforementioned limitations in mobility make lethal payload employment unlikely, unless the armed UGV is used in non-dynamic missions like physical site security, or entry control point monitoring.²⁷ UGVs are too slow to avoid enemy fire and lack Artificial Intelligence (AI) to tell them to seek cover in order to survive.²⁸

Analytical Point #2

To effectively receive commands from the operator through the OCU, solid communications must be maintained. RSTA-specific UGVs can operate tethered to the OCU, rather than tele-operation through radio frequency. This is done for several reasons; most importantly to ensure no transmission is lost thereby losing the UGV. One of the reasons UAS technologies have been more aggressive in their development than the UGV is the fact that UAS communication's architecture, including command and control nodes, pre-existed and the maneuver space aircraft use contains less obstructions to the command and control links from Ground Control Station to the UAS.²⁹ Non-line of sight or Beyond Line of Sight (BLOS) operation is limited to a UGV's ability to send and receive communications. Radio Frequency Interference and Electro-Magnetic Interference are prevalent on the ground and cause signal degradation during UGV tele-operation. Radio propagation technology, i.e. antenna research is critical during UGV design, and can be the deciding factor in how far BLOS the vehicle will be able to operate in different environments.³⁰ Directional and omni-directional antennae and their location/orientation on or within the UGV facilitate communications and mobility.

Unfortunately, IW is often fought in populated areas where urban canyons and man-made EMI degrade remote control operation. To counter this problem, some systems have semi-autonomous capabilities incorporated in their design that command the UGV to backtrack a specified distance should total loss of communication with the OCU occur.

Until these issues are solved and communication reliability is elevated to a higher level, it is unlikely that armed UGVs will see much service in future conflicts where population density is high as there is no room for error in transmission of fail-safe commands or targeting data, especially in IW where the population may be in the line of fire. For autonomous armed UGVs to have a chance, they would be required to maintain a near 100% reliability rating in communications, software, and develop an ability to understand the external environment as at no time could the user afford a runaway system that has the ability to kill both non-combatants and friendly forces.

Analytical Point #3

Autonomy was mentioned in the previous section, as a means of ensuring limited/no loss of the UGV from communications interference by providing the system with rudimentary artificial intelligence to execute tasks on its own. Autonomy, in a larger context when discussing UGV development, indirectly refers to the limits we will allow the operator to separate his or herself from control of the vehicle. Proponents of UGV development often take the position that their efficacy lies in the potential for reducing manpower requirements as the robot assumes human tasks or functions, e.g. logistics support.³¹ Those that advocate armed UGV use also see the potential for less warfighters being sent into combat, as robots take up positions and conduct tactical tasks in place of the human.

Early manpower assessments regarding UGV capabilities came to the conclusion that one individual could be trained to operate multiple tele-operated systems.³² This assessment was later proven inaccurate, as the minimum ratio for operator-UGV control is 1:1 as seen in many of the RSTA-specific UGVs used in Iraq and Afghanistan.³³ For larger, more complex systems that incorporate complicated EO/IR suites or lethal payloads, the ratio jumps to 2:1 and 3:1.³⁴ The complexity of military operations, especially where lethal force may be employed remotely through an unmanned system, requires more than one controller to move the vehicle, operate the weapon system, and maintain situational awareness.³⁵ Experimentation by the Team Performance Lab at the University of Central Florida demonstrated that 2-person UGV control teams better executed simple UGV tasks in an urban setting as compared to single individuals.³⁶ Autonomous or AI capability in UGVs could certainly reduce these ratios by enabling the vehicle to act or think on its own. One operator could “monitor” multiple UGVs and only remain in the loop to authorize lethal force.³⁷

Additional experimentation of targeting scenarios where one individual controlled several tele-operated systems demonstrated degradation in the ability to effectively monitor multiple scenarios. Automated targeting recognition aids have been developed to assist in this area, but still fall short in helping operators overcome their attention deficits when multiple scenarios are being played out remotely.³⁸

Current armed UGVs do not possess the levels of autonomy or AI to assist in dealing with dynamic situations, uncertainty, or ambiguity in the face of incomplete information. They are unable to distinguish between non-combatants and combatants who wear the same clothes or carry the same weapons. RSTA-specific UGVs are fairly simple, but could easily be advanced with mission payloads to support logistic missions, biometric tasks, or identify patterns of life

while occupying semi-permanent positions, without the need for autonomy.³⁹

Questions concerning autonomy and lethal capability in UGVs abound. What happens if the fail-safe system does in fact fail? Is the U.S. developing capabilities just because it can, without forethought as to the consequences should something go wrong?⁴⁰ There is research being conducted within the Office of Naval Research that deals with the levels of independence afforded by autonomous programs in UAS. Mixed Initiative Machine Instructed Computing (MIMIC) is aiding UAS at working more independently by gathering knowledge from human interaction and embedding it into Ground Control Stations.⁴¹ Collaborative Optimization System for Mixed-Initiative Control, or COSMIC focuses on large-scale military operations to provide a collaborative environment where operators will be able to control multiple systems.⁴²

Hopefully the outcome of these two programs can be applied to autonomous UGV development, increasing their interaction with warfighters and other unmanned systems. Even if armed UGVs are developed with significantly advanced levels of AI and can reliably operate autonomously in and amongst troops or in forward areas, questions and concerns about the moral, ethical, and legal consequences surface and must be answered before advancing this level of robotic capability.

Focus Area 2 Conclusion

There is no question as to the value of current RSTA-specific UGV mobility, communications, or autonomy, as seen in the continued procurement and fielding of these systems in support for the War on Terror. They have been designed around the assumption that the distances for their remote operation would not exceed the using organization's ability to cover it with small arms fire. They have a minimal BLOS capability, but can be moved forward

of friendly positions in most terrain, and lie in wait, monitoring their surroundings for potential enemy activity. They can advance into areas where human presence is not feasible and sift through the ground to determine if an IED is present, then carry out the tasks of rendering it safe.

But due to the mobility shortfalls attributed to tele-operation through OCUs, coupled with communications interference, these systems are not ready to assume combat roles alongside warfighters because they move too slowly and take too long in providing enough information for the operator to effectively interpret their surroundings. The fact that IW takes place in urban areas the majority of the time, requires significant amounts of research and development in advancing mobility and communications capabilities in UGVs to enable them to operate alongside dismounted troops in this environment.

In 2004 during the battle for Fallujah, Iraq, it was estimated that one platoon of Marines took approximately six hours to clear 54 houses. Fallujah is 5 kilometers square, and contains around 39,000 structures. Two infantry battalions, with three rifle companies each working 16-hour days, required 20 days to clear all buildings in a very fluid and dynamic operation.⁴³ Given the fact that no UGV can climb stairs at the same rate a human can, one can see how long this mission may have taken if robotics were used to clear rooms, instead of Marines.

RSTA-specific UGVs could have been integrated in the outer security, as part of the cordon force, moving down potential avenues of approach and sending back data on what may be around the next corner, or two.

HRI in support of military operations continues to be defined by their use in ordnance disposal and UAS operations.⁴⁴ Until UGVs can overcome the spatial relationship issues through the use of OCUs and advance autonomous behavior, it is unlikely that armed systems will ever gain military acceptance. Even if armed UGVs are developed with significantly advanced levels

of AI and can reliably operate autonomously in and amongst troops or in forward areas, questions and concerns about the moral, ethical, and legal consequences surface and must be addressed.

Focus Area 3: Ethical, Moral, and Legal Issues

The hopes of military leaders, engineers, and lawmakers that one day robotics will supplement human counterparts in most military tasks, including combat, certainly has merit.⁴⁵ An ability to deploy an armed robot into an environment where it uses sensory and psychomotor capabilities akin to a human being to hunt down and kill the enemy without jeopardizing friendly lives seems logical.⁴⁶ Why not develop UGVs so they may be sent to conduct the most dangerous of operations in warfare?

Autonomous armed UGVs will require an ability to execute cognitive processes as they navigate through the environment before humans will rely on them, and this level of AI has not yet been fully developed. If in the future the U.S. succeeds at developing armed UGVs with the required level of artificial intelligence (AI) or autonomy that decision-makers feel comfortable in approving their use in IW, or even conventional war, legal, moral, and ethical concerns must be addressed before these systems are deployed. The final section of this paper will highlight those concerns as related to IW primarily, but also to conventional war as well.

Analytical Point #1

Advancing armed UGV technology to the point where it can reliably hunt down and kill the enemy through either tele-present or autonomous operation begs the question, is it morally or ethically acceptable to do so? The just war tradition of *jus ad bellum* (guiding a country in

determining if military response to aggression is warranted) and *jus in bello* (guiding a nation in determining the level or proportion of response to that aggression) should be discussed when considering armed UGV development.⁴⁷ These two moral foundations on which the U.S. determines the use of and level of force employed against foreign adversaries is an important discussion point within the framework of lethal unmanned system development.

Armed autonomous UGVs must be capable of delivering proportionate levels of lethal force while discriminating between combatants and non-combatants, considered requirements under *jus in bello*.⁴⁸ In IW, there is often no distinction between the enemy and the civilian population as they may be one in the same, and warfighters must therefore wait until the HA/HI is identified before lethal force can be employed. Unless the system is tele-operated and several personnel are able to identify these enemy activities through the UGV's sensor suites, it is hard to imagine a commander willing to accept the risk associated with autonomous killing in such complex situations.

Using asymmetric tactics, enemy forces in IW often use human shields as a means of deterring U.S. ability to discriminate targets or fire lethal systems. Is it cost effective to develop AI to the degree that systems may in fact be able to single out threats amongst a human population? Is it possible for UGVs to one-day exercise better ethical judgment than humans when placed in shoot/no-shoot scenarios?⁴⁹ From a deterrent standpoint, having an armed fleet of unmanned systems, both ground and air capable, may persuade potential adversaries from certain actions, especially if these systems are overtly introduced into a Commander's Area of Responsibility. This effect is akin to the introduction of first-strike systems like the F-22 into theater and can be seen as a positive outcome if the threat is deterred without having to fire a shot in anger. On the other hand, a country that designs an unmanned

system to the degree that most, if not all other nations have no response for, are we then entertaining the possibility of an unmanned systems arms race? Would this greater military divide between countries force those lacking in robotic technology to seek other means to counter the capability, e.g. Weapons of Mass Destruction? The concept of developing a fleet of unmanned lethal systems to force belligerents to capitulate might have the reverse effect where the opponent seeks extreme measures when faced with a no-win situation, i.e. where the death of their people is grossly out of proportion to the destruction of a lone unmanned system.

Robert E. Lee once said, “it is good that we find war so horrible, or else we would become fond of it.”⁵⁰ The U.S. will likely maintain a responsible protocol for using armed unmanned systems, but should the technology fall into the hands of rogue states, or terrorists, the potential outcome could be disastrous. It is possible that oppressive regimes that have lethal unmanned technology might become more willing to wage war. Rapid proliferation of lethal unmanned systems may cause unnecessary harm to the world where loss of life for one belligerent is grossly out of proportion to another that is employing lethal robotics in a non-discriminatory manner. Careful consideration on the moral and ethical ramifications of unmanned war should be included in any armed UGV program.

Analytical Point #2

From a legal perspective, armed autonomous and semi-autonomous UGVs will likely pose challenges regarding accountability for robotic actions where lethal force was employed.⁵¹ Acknowledging the legal ramifications of fully autonomous lethal force, the Office of the Secretary of Defense in the Fiscal Year 2009-2034 Unmanned Systems Integrated Roadmap, made it clear that the decision to pull a trigger, or in this case press a button with the intent of

employing lethal force will not be fully automated, and remain under the control of human beings.⁵² Regardless of this fact, there are still potential scenarios where collateral damage is inflicted by an armed UGV, resulting in legal issues for the unit controlling it. Does the international community need to develop unmanned system war crimes?⁵³ As discussed under the moral and ethical considerations, if lethal unmanned systems should end up killing the wrong people, who will be held accountable... the developer, the controller, or the parent command? It is conceivable that UGV related ROE might be required in order to protect both the combatant's rights and the force controlling the system, especially in IW.⁵⁴ Even if the human remains in the loop for lethal force employment, per DOD guidance, there still remains the chance that humans will make mistakes, trusting what the computer is telling them to do. On July 3, 1988, the crew of the USS Vincennes inadvertently shot down Iran Flight 655 with 290 civilians aboard over the Persian Gulf when the Aegis computer declared it as a hostile Iranian F-14.⁵⁵ Again in 2003, U.S. Patriot Missile batteries shot down two allied planes as the target acquisition systems identified them as hostile tracks.⁵⁶ There is a fine balance associated with how much trust one has in computer driven systems and how far that trust extends with regards to allowing the accomplishment of tasks automatically.

Focus Area 3 Conclusion

Consideration on the moral, ethical, and legal ramifications must be made surrounding armed UGV development, prior to their consideration for procurement. Irresponsible use of the system in experimentation, training, or real-world use could set back overall UGV development years, if not decades. Collateral damage from lethal UAS use has occurred in the War on Terror, and is deemed acceptable under the *jus in bello* theory that appropriate discrimination and

proportionality were used during the targeting process. For those that believe one-day armed UGVs will operate alongside warfighters in combat, the support mechanisms for both vehicle, payload, and situational awareness aspects of the system will all have to discriminate friend from foe, while determining the appropriate level of force the system will employ. Legal issues derived from fratricide or collateral damage to friendly populations will need further examination before the U.S. commits to any UGV development outside the RSTA-specific realm.

Overall Conclusion

The thought of waging war remotely, through the use of autonomous/semi-autonomous systems may be attractive to some, but the reality is technology can only provide assistance to the warfighter and not fight war in place of humans. The fog and friction associated with war is compounded in IW, where combatants and non-combatants share the same homes, roads, clothes, and culture. It is in some ways inconceivable to take the lethal UAS model of attacking enemy personnel remotely, and apply it to UGVs. UGV shortfalls in mobility, communications, and autonomy force the current systems into tightly controlled mission scenarios, e.g. perimeter security, logistical resupply, or counter-IED missions.

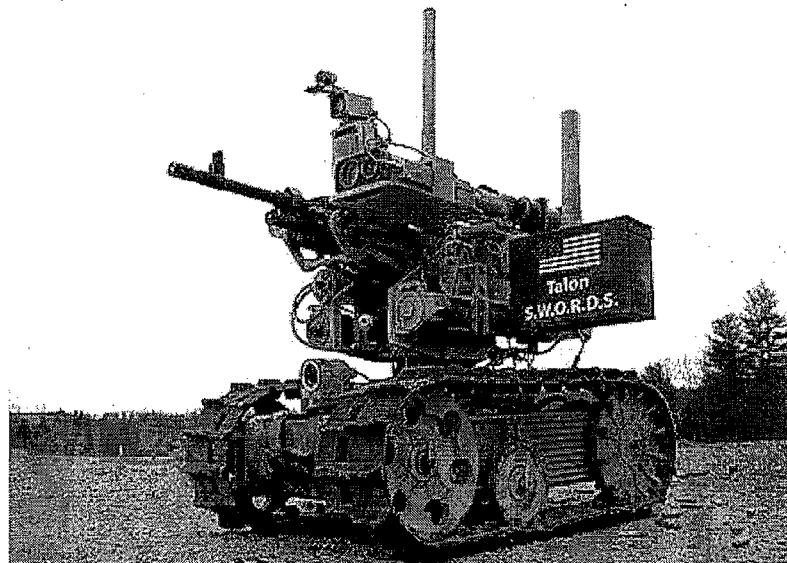
There exist no algorithms for UGVs that ensure their behavior falls within ethical boundaries or moral constraints when faced with a life or death situation.⁵⁷ This cognitive process is left up to the warfighter, and should remain so. As the U.S. continues to invest in unmanned technology, research must be made to address the moral, ethical, and legal issues surrounding remotely controlled lethal capabilities that will undoubtedly affect all levels of warfare, tactical through strategic. Research should include identifying metrics for ethical and

moral reasoning as a core component of any autonomous development, regardless of where the DOD stance is on automated lethal force.

If the overwhelming requirement in Afghanistan, as witnessed in Iraq, is for increasing the situational awareness of the small unit due to the decentralization of operations, future RSTA-specific capabilities should be developed in modular payload form, e.g. reconnaissance and surveillance, target identification, Chemical, Biological, Radiological, and Nuclear detection, and advanced EOD capability. If the IED is the weapon of choice for irregular threats, furthering the development of RSTA-specific UGVs that can take the place or augment mechanical route clearance teams may be a step in the right direction at maintaining mobility throughout an operating area. Removing the man from the task of route clearance also reduces the likelihood of enduring the concussive effects of a high-order detonation.⁵⁸

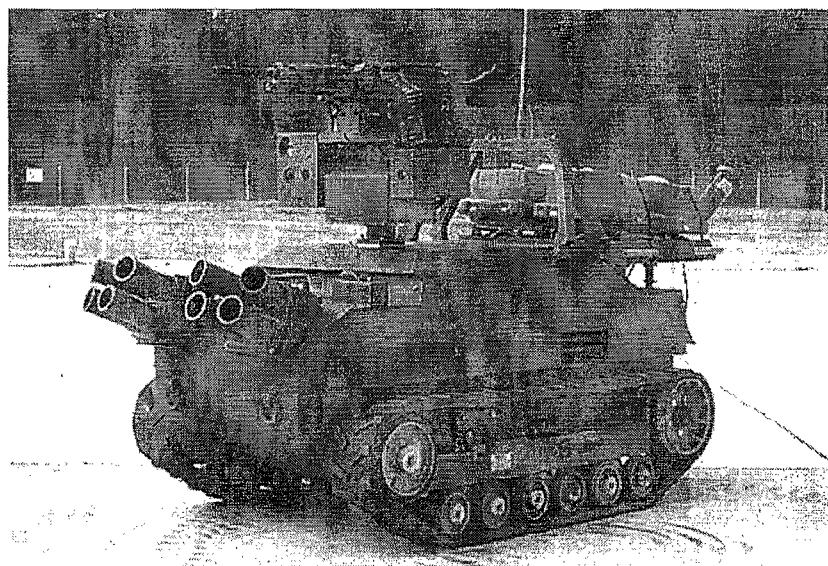
The DOD UGV developmental roadmap should follow the historical UAS model, focusing on developing a means to increase the effectiveness of the warfighter by aiding in target acquisition/identification of enemy forces, accessing locations of the battlefield that are impractical for a human to do so, or execute the mundane tasks of moving supply items from point A to point B in rear areas. In the end, due to the array of technological shortfalls, and the legal, moral, and ethical issues surrounding unmanned lethal capabilities, UGV development should be focused at meeting the challenges associated with IW as Reconnaissance, Surveillance, and Target Acquisition (RSTA) platforms, not as systems capable of employing lethal force on the battlefields of tomorrow.

Appendix A



Above Image: SWORDS - Special Weapons Observation Reconnaissance Detection System

Source: <http://military.discovery.com/technology/robots/medium-ugv/swords.html>



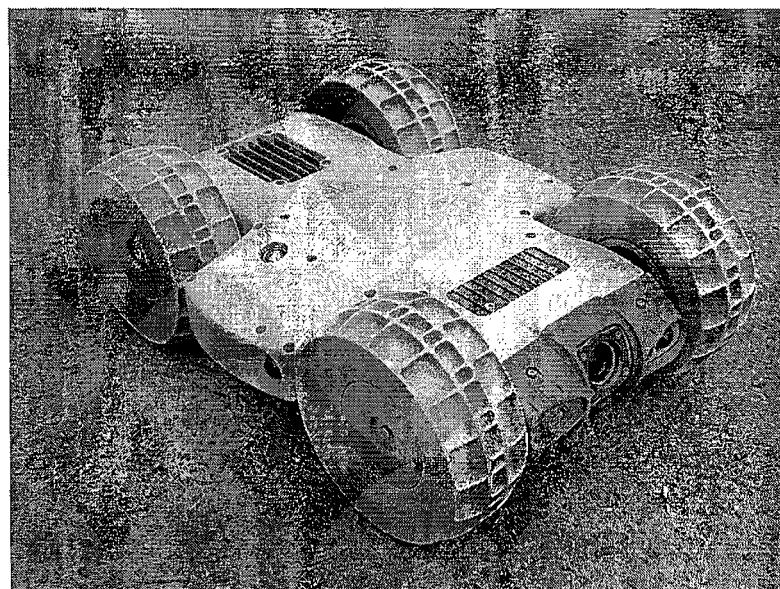
Above Image: GLADIATOR Unmanned Ground Vehicle

Source: <http://www.defenseindustrydaily.com/usmc-gladiators-to-pack-a-swarm-01198/>

Appendix B

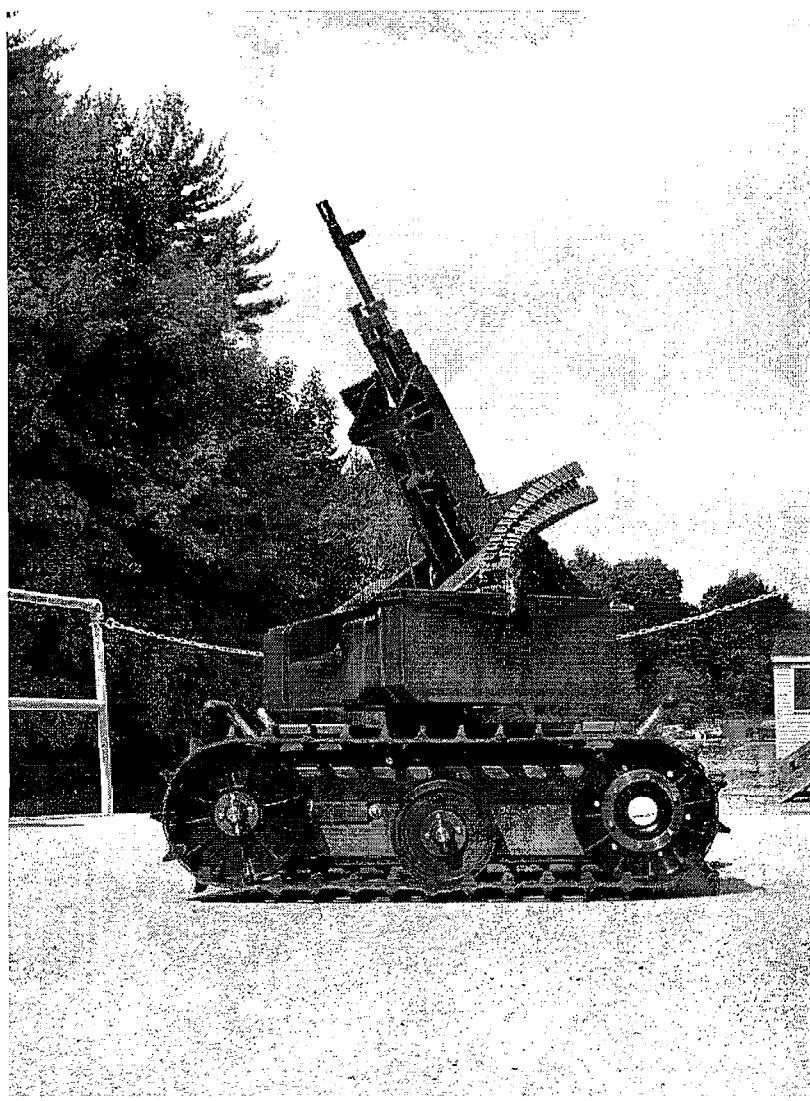


Above Image: German GOLIATH Unmanned Ground Vehicle
Source: <http://www.ww2incolor.com/britain/Golias.html>



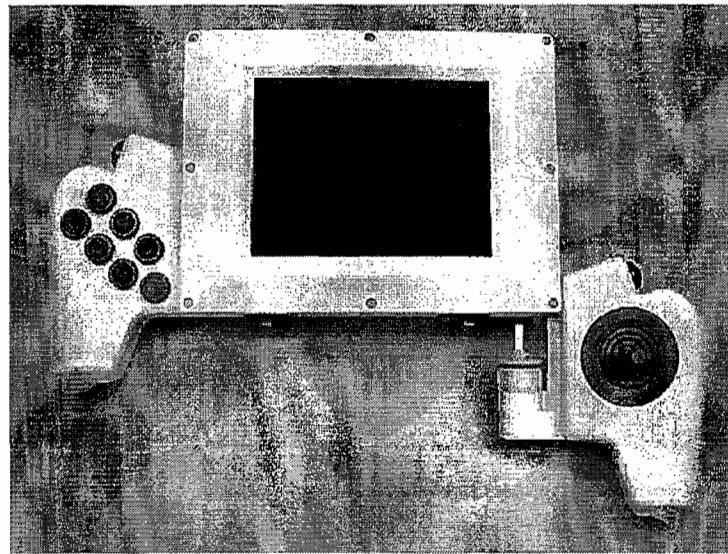
Above Image: DRAGON RUNNER Unmanned Ground Vehicle
Source: Major David Moreau/USMC

Appendix C



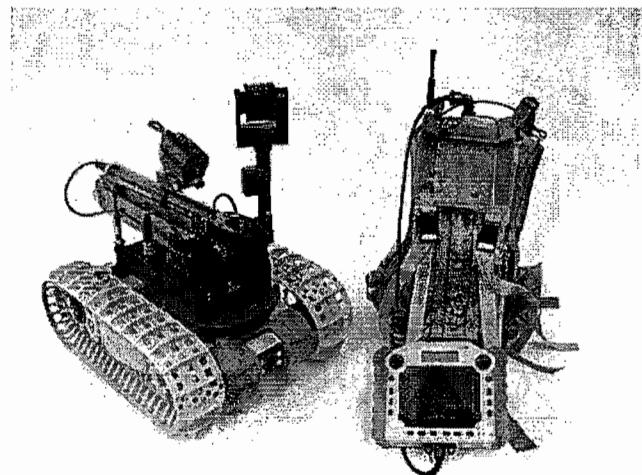
Above Image: MAARS: Modular Advanced Armed Robotic System
Source: <http://foster-miller.qinetiq-na.com/lemming.htm>

Appendix D



Above Image: Example of UGV Operator Control Unit (OCU)

Source: <http://www.spawar.navy.mil/robots/resources/Common%20OCU/Common%20OCU.htm>



Above Image: Example of Operator Control Unit with RSTA-Specific UGV system

Source: <http://inhabitat.com/britains-new-dragon-runner-robot-deactivates-live-explosives/dragon-runner-with-backpack/>

Endnotes

¹ Rod Paschall, *LIC 2010: Special Operations & Unconventional Warfare in the Next Century*, (McLean, VA, Brassey's, 1990), 5.

² United States Marine Corps, *Small Wars Manual*, (Washington, DC, United States Government Printing Office, 1940), 15.

³ Department of Defense, *National Defense Strategy, 2008*, (Washington, DC, United States Government Printing Office, 2008), 4.

⁴ Roxana Tiron, *Ground Robotics Experience Bumpy Ride*, (Arlington, VA, National Defense, National Defense Industrial Organization, Vol. 87, Issue 586, 2002), 33.

⁵ Armin Krishnan, *Killer Robots: Legality and Ethicality of Autonomous Weapons*, (Surrey, UK, Ashgate, 2009), 90.

⁶ Ibid, 17.

⁷ United States Navy, National Air and Space Museum, Smithsonian Institution webpage. <http://www.nasm.si.edu/exhibitions/gal104/uav.cfm> (accessed 05 January, 2011)

⁸ Krishnan, 7.

⁹ P.W. Singer, *Robots at War: The New Battlefield*, (Washington, DC, The Wilson Quarterly, Vol. 33, Issue 1, 2009), 32.

¹⁰ Krishnan, 2.

¹¹ Ibid, 4.

¹² United States Congress, S.2549, Sec. 217, 2001.

¹³ Department of Defense, *Department of Defense Directive 3000.07, Irregular Warfare 2008*, (Washington, DC, United States Printing Office, 2008), 1.

¹⁴ Michael L. Gross, *Moral Dilemmas of Modern War*, (Haifa, Israel, University of Haifa, 2010), 13.

¹⁵ Joseph D. Celeski, *Hunter-Killer Teams: Attacking Enemy Safe Havens*, (Hurlburt Field, FL, Joint Special Operations University, 2010), 8.

¹⁶ Alec Wahlman, *Improving Capabilities for Irregular Warfare*, (Alexandria, VA, Institute for Defense Analysis, 2007), II-5.

¹⁷ Celeski, 60.

¹⁸ Paschall, 146.

¹⁹ Wahlman, I-4 & I-5.

²⁰ United States Marine Corps, *Marine Corps Operating Concept*, (Washington, DC, United States Government Printing Office, Marine Corps Combat Development Command, 2010), 95.

²¹ Carter Malkasian and Daniel Marston, *Counterinsurgency in Modern Warfare*, (Oxford, UK, Osprey Publishing, 2008), 15.

²² Gross, 35.

²³ United States Marine Corps, *Marine Corps Operating Concept*, 109.

²⁴ Gross, 35.

²⁵ United States Marine Corps, *Marine Corps Operating Concept*, 121.

²⁶ Linda R. Elliot and Elizabeth S. Redden, "Robotic Control Systems for Dismounted Soldier," in *Human-Robotic Interactions in Future Military Operations*, in *Human-Robotic Interactions in Future Military Operations*, ed. Michael Barnes and Florian Jentsch, 335-354 (Surrey, UK, Ashgate Publishing Limited, 2010), 346.

²⁷ Wahlman, IV-81.

²⁸ Krishnan, 37.

²⁹ Yaniv Minkov and Tal Oron-Gilad, "Remotely Operated Vehicles (ROVs) From the Bottom-up Operational Perspective", in *Human-Robotic Interactions in Future Military Operations*, ed. Michael Barnes and Florian Jentsch, 211-228 (Surrey, UK, Ashgate Publishing Limited, 2010), 211.

³⁰ Henry S. Kenyon, *U.S. Robots Surge onto the Battlefield*, (Fairfax, VA, Signal, Armed Forces Communications and Electronics Association, Vol. 62, Issue 7, 2008), 48.

³¹ Steven M. Shaker and Alan R. Wise, *War Without Men: Robots on the Future Battlefield*, (Dulles, VA, Brassey's, 1988), 9.

³² William A. Evans III and Florian G. Jentsch, "The Future of HRI: Alternate Research Trajectories and their Influence on the Future of Unmanned Systems", in *Human-Robotic Interactions in Future Military Operations*, ed Michael Barnes and Florian Jentsch, 435-442 (Surrey, UK, Ashgate Publishing Limited, 2010), 435.

³³ Ibid, 435.

³⁴ Ibid, 435.

³⁵ Michael J. Barnes and William A. Evans III, "Soldier-Robot Teams in Future Battlefields: An Overview", in *Human-Robotic Interactions in Future Military Operations*, ed Michael Barnes and Florian Jentsch, 9-30 (Surrey, UK, Ashgate Publishing Limited, 2010), 10.

³⁶ William A. Evans III, Florian G. Jentsch, and Scott Ososky, "Model World: Military HRI Research Conducted Using a Scale MOUT Facility", in *Human-Robotic Interactions in Future Military Operations*, ed Michael Barnes and Florian Jentsch, 419-434 (Surrey, UK, Ashgate Publishing Limited, 2010), 428.

³⁷ Chris Jansen and Jan B.F. van Erp, "Telepresence Control of Unmanned Systems", in *Human-Robotic Interactions in Future Military Operations*, ed Michael Barnes and Florian Jentsch, 251-270 (Surrey, UK, Ashgate Publishing Limited, 2010), 252.

³⁸ Michael J. Barnes and William A. Evans III, 12-13.

³⁹ Rita Boland, *Developing Reasoning Robots for Today and Tomorrow*, (Fairfax, VA, Signal, Armed Forces Communications and Electronics Association, Vol. 61, Issue 6, 2007), 46.

⁴⁰ Roxana Tiron, *Lack of Autonomy Hampering Progress of Battlefield Robots*, (Arlington, VA, National Defense, National Defense Industrial Organization, Vol. 87, Issue 594, 2003), 34.

⁴¹ Rita Boland, *Military Considers the Human Factor in Independent Robots*, (Fairfax, VA, Signal, Armed Forces Communications and Electronics Association, Vol. 62, Issue 7, 2008), J6.

⁴² Ibid, J6.

⁴³ Wahlman, IV-68.

⁴⁴ William A. Evans III, "An Introduction to Human-Robot Interaction in Military Applications", in *Human-Robotic Interactions in Future Military Operations*, ed Michael Barnes and Florian Jentsch, 3-8 (Surrey, UK, Ashgate Publishing Limited, 2010), 3.

⁴⁵ Ibid, 4.

⁴⁶ Sheryl L. Chappell, Erik S. Connors, Mica R. Endsley, Jennifer M. Riley, and Laura D. Strater, "Robots in Space and Time: The Role of Object, Motion and Spatial Perception in the Control and Monitoring of Uninhabited Ground Vehicles", in *Human-Robotic Interactions in Future Military Operations*, ed Michael Barnes and Florian Jentsch, 171-192 (Surrey, UK, Ashgate Publishing Limited, 2010), 171.

⁴⁷ Jansen and van Erp, 251.

⁴⁸ Douglas J. Gillan, Patricia McDermott, and Jennifer Riley, "The Cognitive Psychology of Human-Robot Interaction", in *Human-Robotic Interactions in Future Military Operations*, ed Michael Barnes and Florian Jentsch, 53-66 (Surrey, UK, Ashgate Publishing Limited, 2010), 54.

⁴⁹ Krishnan, 90.

⁵⁰ Ibid, 98.

⁵¹ Ronald Arkin, *Building Trust in Combat Robots*, (Herndon, VA, Military History, Vol. 24, Issue 7, 2007), 15.

⁵² P.W. Singer, *Robots at War: The New Battlefield*, 32.

⁵³ Stew Magnuson, *Robo Ethics: Debate over Rules, Legality of Robots on the Battlefield Lagging, Experts Say*, (Arlington, VA National Defense, National Defense Industrial Organization, Vol. 94, Issue 672, 2009), 29.

⁵⁴ Ibid, 28.

⁵⁵ Krishnan, 146-147.

⁵⁶ Magnuson, 29.

⁵⁷ P.W. Singer, *Robots at War: The New Battlefield*, 40.

⁵⁸ Ibid, 40.

Bibliography

Arkin, Ronald. *Accountable Autonomous Agents: The Next Level*. Raleigh-Durham, NC: United States Army Research Office, 2009.

Arkin, Ronald. *Building Trust in Combat Robots*. Herndon, VA: Military History, Vol. 24, Issue 7, 2007.

Barnes, Michael J. and Evans III, William J. "Soldier-Robot Teams in Future Battlefields: An Overview." In *Human-Robotic Interactions in Future Military Operations*, edited by Michael Barnes and Florian Jentsch, 9-30. Surrey, UK: Ashgate Publishing Limited, 2010.

Boland, Rita. *Developing Reasoning Robots for Today and Tomorrow*. Fairfax, VA: Signal, Armed Forces Communications and Electronics Association, Vol. 61, Issue 6, 2007.

Boland, Rita. *Military Considers the Human Factor in Independent Robots*. Fairfax, VA: Signal, Armed Forces Communications and Electronics Association, Vol. 62, Issue 7, 2008.

Celeski, Joseph D. *Hunter-Killer Teams: Attacking Enemy Safe Havens*. Hurlburt Field, FL: Joint Special Operations University, 2010.

Chappell, Sheryl L., Connors, Erik S., Endsley, Mica R., Riley, Jennifer M., and Strater, Laura D. "Robots in Space and Time: The Role of Object, Motion and Spatial Perception in the Control and Monitoring of Uninhabited Ground Vehicles." In *Human-Robotic Interactions in Future Military Operations*, edited by Michael Barnes and Florian Jentsch, 171-192. Surrey, UK: Ashgate Publishing Limited, 2010.

Department of Defense, *Department of Defense Directive 3000.07, Irregular Warfare 2008*, (Washington, DC, United States Printing Office, 2008), 1.

Department of Defense, *National Defense Strategy, 2008*, (Washington, DC, United States Government Printing Office, 2008), 4.

Elliot, Linda R. and Redden, Elizabeth S. "Robotic Control Systems for Dismounted Soldier." In *Human-Robotic Interactions in Future Military Operations*, in *Human-Robotic Interactions in Future Military Operations*, edited by Michael Barnes and Florian Jentsch, 335-354. Surrey, UK: Ashgate Publishing Limited, 2010.

Evans III, William A. and Jentsch, Florian G. "The Future of HRI: Alternate Research Trajectories and their Influence on the Future of Unmanned Systems." In *Human-Robotic Interactions in Future Military Operations*, edited by Michael Barnes and Florian Jentsch, 435-442. Surrey, UK: Ashgate Publishing Limited, 2010.

Evans III, William A., Jentsch, Florian G., and Ososky, Scott. "Model World: Military

HRI Research Conducted Using a Scale MOUT Facility.” In *Human-Robotic Interactions in Future Military Operations*, edited by Michael Barnes and Florian Jentsch, 419-434. Surrey, UK: Ashgate Publishing Limited, 2010.

Evans III, William A. “An Introduction to Human-Robot Interaction in Military Applications.” In *Human-Robotic Interactions in Future Military Operations*, edited by Michael Barnes and Florian Jentsch, 3-8. Surrey, UK: Ashgate Publishing Limited, 2010.

Gillan, Douglas J. and Thompson, Lori Foster. “Social Factors in Human-Robot Interaction.” In *Human-Robotic Interactions in Future Military Operations*, edited by Michael Barnes and Florian Jentsch, 67-82. Surrey, UK: Ashgate Publishing Limited, 2010.

Gillan, Douglas J., McDermott, Patricia, and Riley, Jennifer. “The Cognitive Psychology of Human-Robot Interaction.” In *Human-Robotic Interactions in Future Military Operations*, edited by Michael Barnes and Florian Jentsch, 53-66. Surrey, UK: Ashgate Publishing Limited, 2010.

Gross, Michael L. *Moral Dilemmas of Modern War*. Haifa, Israel: University of Haifa, 2010.

Jansen, Chris and van Erp, Jan B.F.. “Telepresence Control of Unmanned Systems.” In *Human-Robotic Interactions in Future Military Operations*, edited by Michael Barnes and Florian Jentsch, 251-270. Surrey, UK: Ashgate Publishing Limited, 2010.

Kenyon, Henry S. *U.S. Robots Surge onto the Battlefield*. Fairfax, VA: Signal, Armed Forces Communications and Electronics Association, Vol. 62, Issue 7, 2008.

Krishnan, Armin. *Killer Robots: Legality and Ethicality of Autonomous Weapons*. Surrey, UK: Ashgate, 2009.

Magnuson, Stew. *Robo Ethics: Debate over Rules, Legality of Robots on the Battlefield Lagging, Experts Say*. Arlington, VA: National Defense, National Defense Industrial Organization, Vol. 94, Issue 672, 2009.

Malkasian, Carter and Marston, Daniel. *Counterinsurgency in Modern Warfare*. Oxford, UK: Osprey Publishing, 2008.

Minkov, Yaniv and Oron-Gilad, Tal. “Remotely Operated Vehicles (ROVs) From the Bottom-up Operational Perspective.” In *Human-Robotic Interactions in Future Military Operations*, edited by Michael Barnes and Florian Jentsch, 211-228. Surrey, UK: Ashgate Publishing Limited, 2010.

Paschall, Rod. *LIC 2010: Special Operations & Unconventional Warfare in the Next Century*. McLean, VA: Brassey's, 1990.

Shaker, Steven M. and Wise, Alan R. *War Without Men: Robots on the Future Battlefield*. Dulles, VA: Brassey's, 1988.

Singer, P.W. *Robots at War: The New Battlefield*. Washington, DC: The Wilson Quarterly, Vol. 33, Issue 1, 2009.

Singer, P.W. *Wired for War: The Robotics Revolution and Conflicts in the 21st Century*. New York, NY: Penguin, 2009.

Tiron, Roxana. *Ground Robotics Experience Bumpy Ride*. Arlington, VA: National Defense, National Defense Industrial Organization, Vol. 87, Issue 586, 2002.

Tiron, Roxana. *Lack of Autonomy Hampering Progress of Battlefield Robots*. Arlington, VA: National Defense, National Defense Industrial Organization, Vol. 87, Issue 594, 2003.

United States Congress, National Defense Authorization, Fiscal Year 2001, Subtitle B, Program Requirements, Restrictions, and Limitations. Section 220. *Unmanned advanced capability combat aircraft and ground combat vehicles*. 106th Cong., October 30, 2000.

United States Marine Corps, *Marine Corps Operating Concept*. Washington, DC: United States Government Printing Office, Marine Corps Combat Development Command, 2010.

United States Marine Corps, *Small Wars Manual*. Washington, DC: United States Government Printing Office, 1940.

United States Navy, National Air and Space Museum, Smithsonian Institution webpage.
<http://www.nasm.si.edu/exhibitions/gal104/uav.cfm> (accessed 05 January, 2011)

Wahlman, Alec. *Improving Capabilities for Irregular Warfare*. Alexandria, VA: Institute for Defense Analysis, 2007.